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WINTER POPULATION OF *LOLIGO PEALEI* IN THE MID-ATLANTIC BIGHT [1]

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The biology of the common Atlantic Coast squid, *Loligo pealei* (Lesueur, 1821), has been described principally from its summer, inshore populations (Verrill, 1882; Williams, 1909; Drew, 1911; Arnold, 1962; Haefner, 1964; Summers, 1968; and others). Migration of these populations is suggested by their annual appearance and disappearance from inshore areas. The offshore populations of *L. pealei* have been only partially described (Summers, 1967). This paper reports attempts to more precisely locate the winter distribution of *L. pealei* and estimate the abundance of this species.

Myopsid squid of the family Loliginidae are reported from the epipelagic zone in the sea, bounded by depths no greater than 200–400 m (Voss, 1967). They are not commonly found over deeper water and appear to be restricted to coastal margins and continental shelves around the world. *L. pealei* has been reported from New Brunswick, Canada (Stevenson, 1934) to Columbia (LaRoe, 1967), however, it is most often encountered between Cape Cod and Cape Hatteras on the East Coast of the United States (Verrill, 1882; LaRoe, 1967). Verrill (1882) reported this species in depths to 92 m and its eggs to half that depth. LaRoe (1967) gave a mean depth of 62 m for his collection of specimens, and Summers (1967) reported the peak offshore abundance of *L. pealei* at approximately 170 m.

The earliest inshore appearance of *L. pealei* in the vicinity of Woods Hole, Massachusetts is reported as: May 7, Bumpus (1898), and ranged from April 16 to May 7 for the years 1900–1910, (V. N. Edwards, cited by Sumner, Osburn and Cole, 1913). The offshore migration of this animal is less distinct and reported to take place in early November (Verrill, 1882). The latest trawl catches of *L. pealei* resulting from biweekly sampling near Woods Hole occurred on November 16, 1967 (Summers, 1968) and November 15, 1968 (Summers, unpublished).

Bigelow (1924, p. 113) suggested that *L. pealei* did not disappear from the inshore areas, and presumed that ". . . it passes the cold season inshore on the bottom." He was not aware of this species being reported from the offshore banks in summer nor from deep water. Though his writing indicates that he was experienced with this animal, Bigelow stated that he had not taken a single specimen of *L. pealei* in his "tow nets."

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The European species, *Loligo vulgaris*, is tentatively reported to have an annual coastwise migration in the North Sea (Tinbergen and Verwey, 1945); these authors state that descriptions of the autumnal migration and winter location of this squid are uncertain (p. 282). In the western Mediterranean Sea, *L. vulgaris* is reported to exhibit a seasonal vertical migration which brings it onshore in the spring and takes it offshore in the autumn (Mangold-Wirz, 1963, p. 140). With apparent reference to Verrill's work, Mangold-Wirz compared the latter migration with that of *L. pealei*. These two reports on *L. vulgaris* are based upon animals obtained from commercial fishing vessels and may incorporate some bias from these sources due to gear selectivity and the incidental nature of squid catches.

Methods

Approximately five metric tons of *L. pealei* were collected with commercial North Atlantic otter trawl nets during four cruises listed in Table I. The first

Table I

Winter otter trawl surveys in the mid-Atlantic Bight

Year	1966	1967	1967	1968
Vessel	Delaware	Delaware	A. T. Cameron	Albatross iv
Cruise No.	66–11	67–1	130	68–3
Dates	XI 29–XII 15	II 2–II 21	III 16–IV 13	III 4–III 22
Area, Cape Hatteras to:	Hudson Canyon	Hudson Canyon	Georges Bank	Georges Bank
Otter trawl	#41	#41	#41/5*	#36
Mesh size, mm†	127–114	127–114	127–13	127–13
Headrope, m	24.4	24.4	24.4	18.3
Footrope, m	30.5	30.5	30.5	24.4
Tow speed, km/hr	6.5	6.5	6.5	6.5
Tow time, hr	1	1	½	½
Day/night	Day	Day	Day	Day & night
Depths, m	18–183	18–732	82–1465	27–366
No. of tows	42	54	35‡	159‡
No. *L. pealei* measured	None	1480	3352	3343
Per cent sexed	—	51	51	15

* A #41 otter trawl with an extension piece between the belly and the cod end.

† Stretched measure including one knot.

‡ Number of tows within the sampling area shown in Figure 1. Additional stations were made to the north, and the A. T. Cameron fished in waters deeper than 366 m.

three cruises were spaced through the winter of 1966–1967 and the fourth cruise was made in the late winter of 1968, one year after the third cruise. Two cruises made by the R/V Delaware were parts of a single exploratory survey of the continental shelf and slope and do not represent duplication in sampling. Sampling conditions and cruise ranges are given in Table I. Cephalopod species were separated during the last three cruises and 97% of the individuals were *L. pealei;* the remainder were mostly *Illex illecebrosus*. Because of the dominance of *L. pealei* in these collections, I assume that data for "squid" catches on Delaware cruise 66–11 were representative for the one species.

DELAWARE cruises 66–11 and 67–1 were conducted by the U. S. Bureau of Commercial Fisheries, Exploratory Fishing and Gear Research Base, Gloucester, Massachusetts. Catch data for these cruises were provided by Mr. E. D. McRae. Mr. Clarence Butt of the Fisheries Research Board of Canada measured and sexed samples of *L. pealei* during the second cruise. The DELAWARE otter trawl net was unlined and probably was not efficient in retaining small squid (see Summers, 1968). Sampling on these cruises was performed on transect lines perpendicular to the coast during daylight hours.

R/V A. T. CAMERON cruise number 130 was conducted by the Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland. This cruise was primarily concerned with a study of the oceanic squid, *I. illecebrosus*, between Nova Scotia and Cape Hatteras (Mercer, 1969). The Scientist-in-Charge, Mr. M. C. Mercer, invited me to participate during part of the cruise between Cape Cod and Cape Hatteras. The CAMERON otter trawl net was lined with a fine mesh liner and, as in the previous survey, sampling was restricted to daylight hours and to transect lines perpendicular to the coast.

R/V ALBATROSS IV cruise 68–3 was conducted by the U. S. Bureau of Commerical Fisheries, Biological Station, Woods Hole, Massachusetts as a part of its regular groundfish survey program. At the invitation of Dr. M. D. Grosslein, I participated during the entire cruise. Later cruises extended the groundfish survey to the waters surrounding southern Nova Scotia. The ALBATROSS IV used a lined otter trawl net which was smaller than those employed during the earlier cruises. Sampling conformed to a stratified random sampling design and operations continued both day and night (Grosslein, 1969). Geographical subdivisions from this design were used for the comparison of all of the cruise data resulting from the four cruises.

The region sampled (Figure 1) was confined to the offing between Cape Cod and Cape Hatteras (the mid-Atlantic Bight) with an eastward extension to include Georges Bank. The portion of the Bureau of Commercial Fisheries survey area used in this study is shown in the figure; this is subdivided by nine coastal zones (designated here by Roman numerals), each of which includes a set of strata corresponding to four depth zones. Depth zones are unequal in area and bounded by smoothed contours for depths of 27, 55, 110, 183 and 366 m. Thus, the region sampled is partitioned by a nine by four matrix except that the shallowest depth zone is not divided between coastal zones VIII and IX, an inconsistency which does not affect the present study. The continental shelf break occurs roughly at 120 m depth on Georges Bank and gradually decreases in depth to about 80 m off of Cape Hatteras; this separates approximately equal numbers of matrix cells either side of the shelf break.

Hydrographic measurements and catch records on the sampling cruises followed established practices for the various agencies and vessels. The catches of *L. pealei* were recorded by station (one tow per station) with some combination of data including weight, volume or number of individuals. On the last three cruises, length-frequency, sex and maturity were recorded for samples of up to several hundred individuals. Dorsal mantle lengths were measured from fresh squid to the nearest whole centimeter and maturity was established relative to arbitrary stages of gonadal development (Haefner, 1964; Summers, 1968).

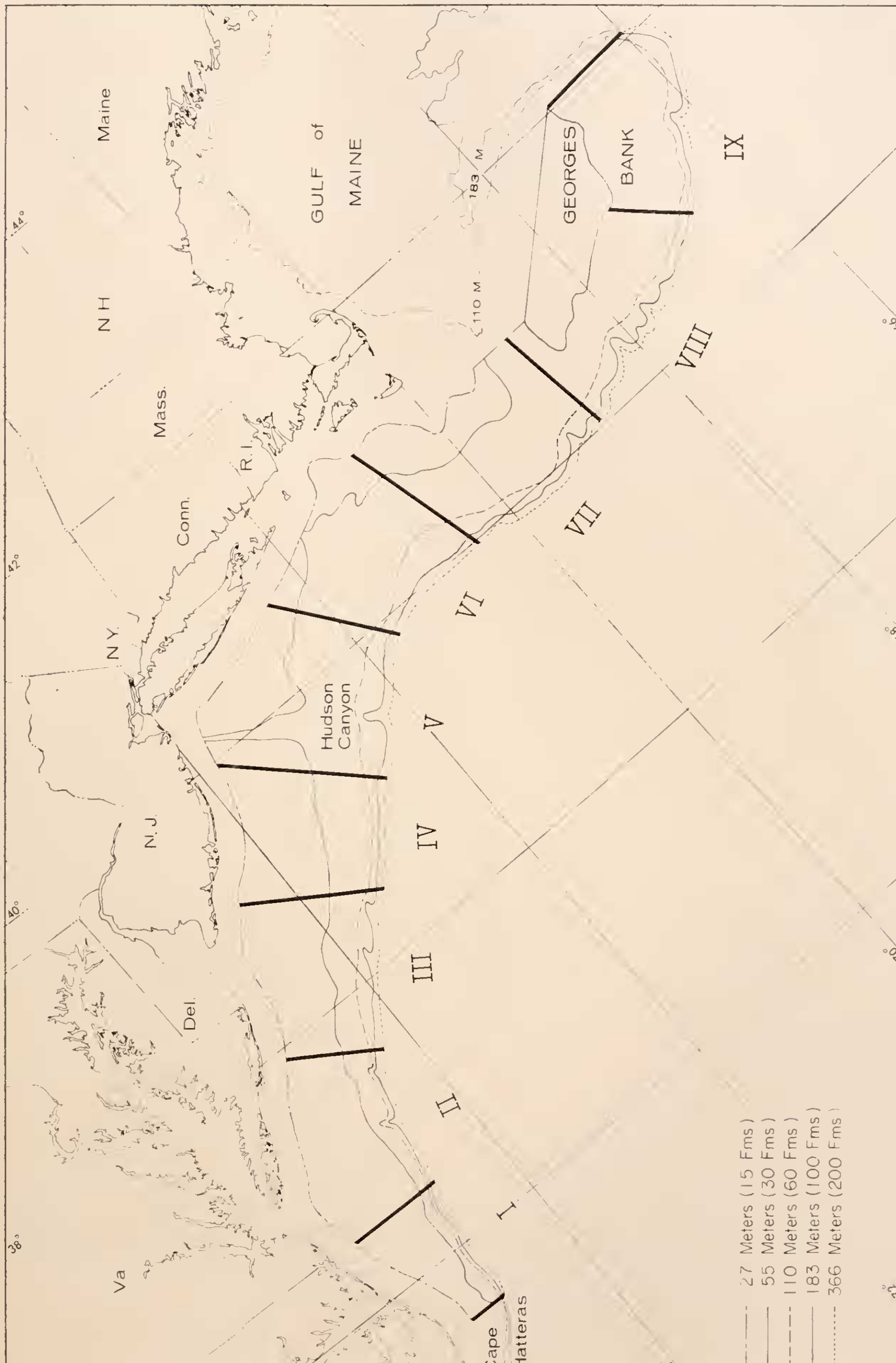

FIGURE 1. The mid-Atlantic Bight and Georges Bank showing the sampling region and its subdivision by coastal zones (designated here by Roman numerals) and four depth zones.

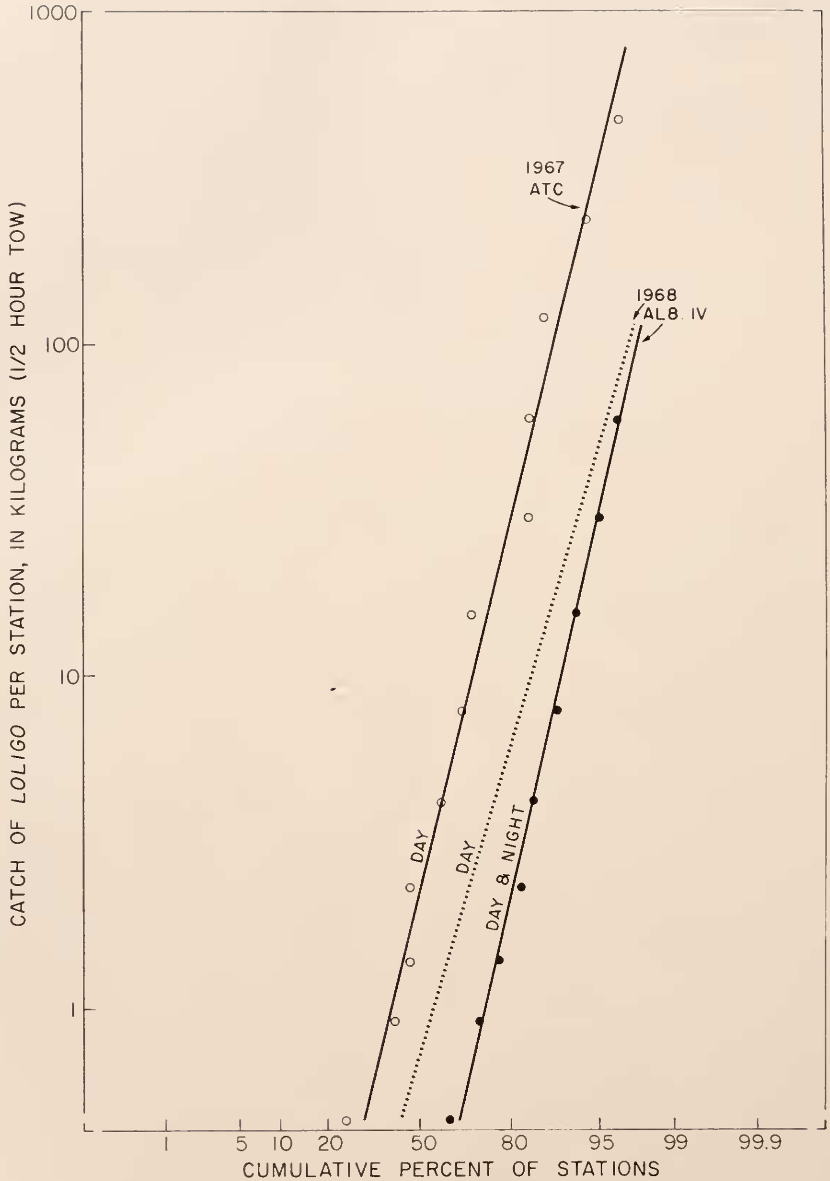

FIGURE 2. Log probability presentation of catches of *L. pealei* per tow for two late winter cruises. Straight lines in this figure represent lognormal frequency distributions of catches per tow. The 1967 cruise and dotted line data for the 1968 cruise are for daytime trawling only; the solid line for the 1968 cruise is approximately equally weighted for day and night trawling.

RESULTS

Because of my personal acquaintance with the cruises of the CAMERON and ALBATROSS IV, and since these are representative of the largest area and a single time of year, I will base most of the following results upon them and draw upon the DELAWARE data only for comparison.

Catches of *L. pealei* varied considerably from station to station for standardized tows. Frequency distributions of catches per tow showed a large positive skewness for all of the cruises. This, in itself, is a good indication of "patchiness" in the

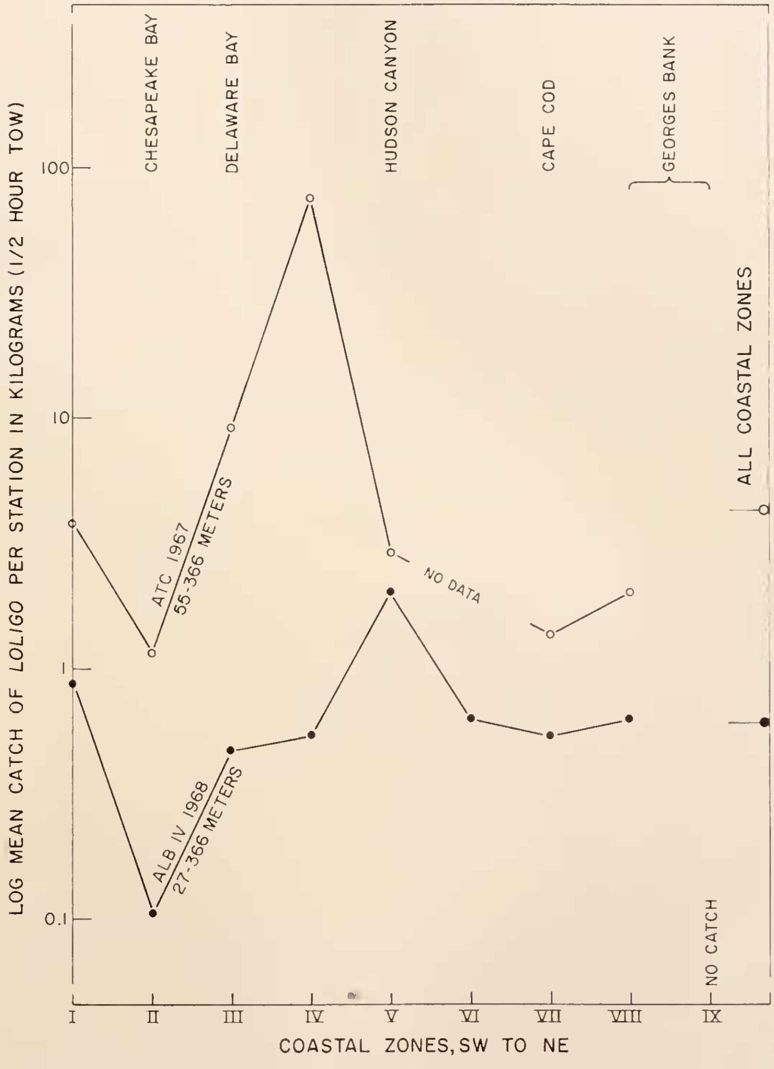

FIGURE 3. Log mean catches of *L. pealei* per tow for the nine coastal zones in 1967 and 1968. Overall log mean catches are shown at the right margin.

distribution of *L. pealei,* since a uniform distribution should produce a symmetrical catch per tow histogram. Figure 2 shows a log probability presentation of the catch per tow data for the last two cruises; straight lines on this figure represent lognormal catch per tow histograms. The straight line fit of data points in Figure 2 suggests that the catch data can be treated by normal statistics after a log transformation. (Lognormal models are useful in biology where logs of the variate are normally distributed. In this application, the biomass of *L. pealei* resulting from a standardized tow forms an approximate geometric series which can be fitted by a lognormal model.)

As is apparent from Table I, the two cruises represented in Figure 2 had substantial differences in sampling, including years, gear, depths and hours of sampling. Since both cruises extended through the time of the vernal equinox, it was practical to separate day catches from night catches at arbitrary mid-tow times of 6:00 AM and 6:00 PM. The solid line for 1967 and the dotted line for 1968 represent day catches as shown in Figure 2.

The remaining differences in sampling and the subsequent analysis of factors relating to the distribution and abundance of *L. pealei,* requires some average measure of the catch per tow data. The lognormal catch per tow histogram suggests a log mean for this purpose, or the mean of the log transformation of the

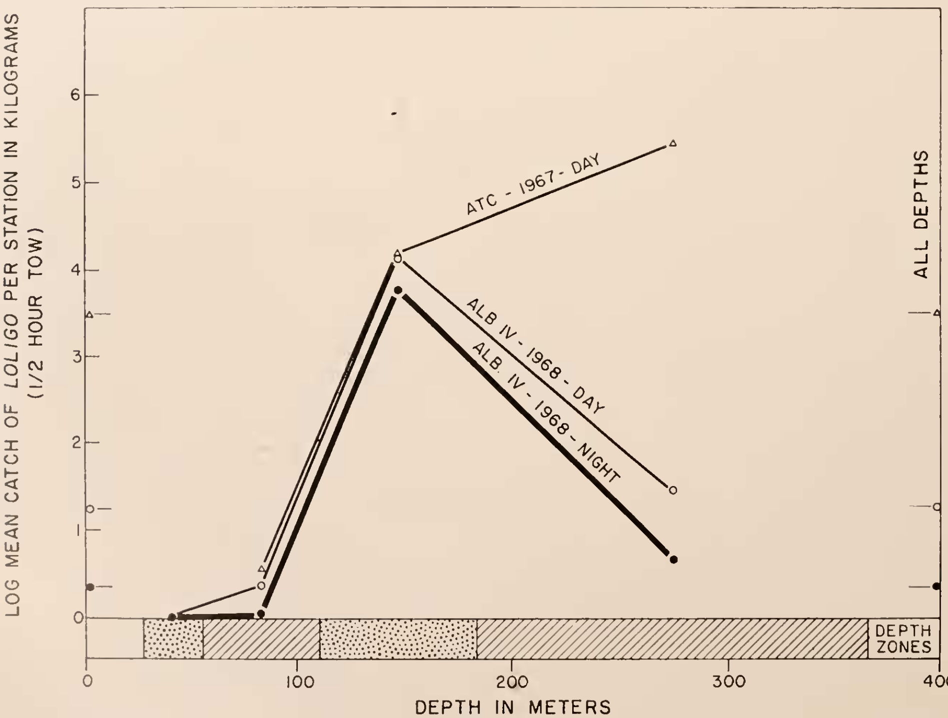

FIGURE 4. Log mean catches of *L. pealei* per tow for the four depth zones in 1967 and 1968. The 1968 data is separated into day and night portions and overall log mean catches are shown at the right margin.

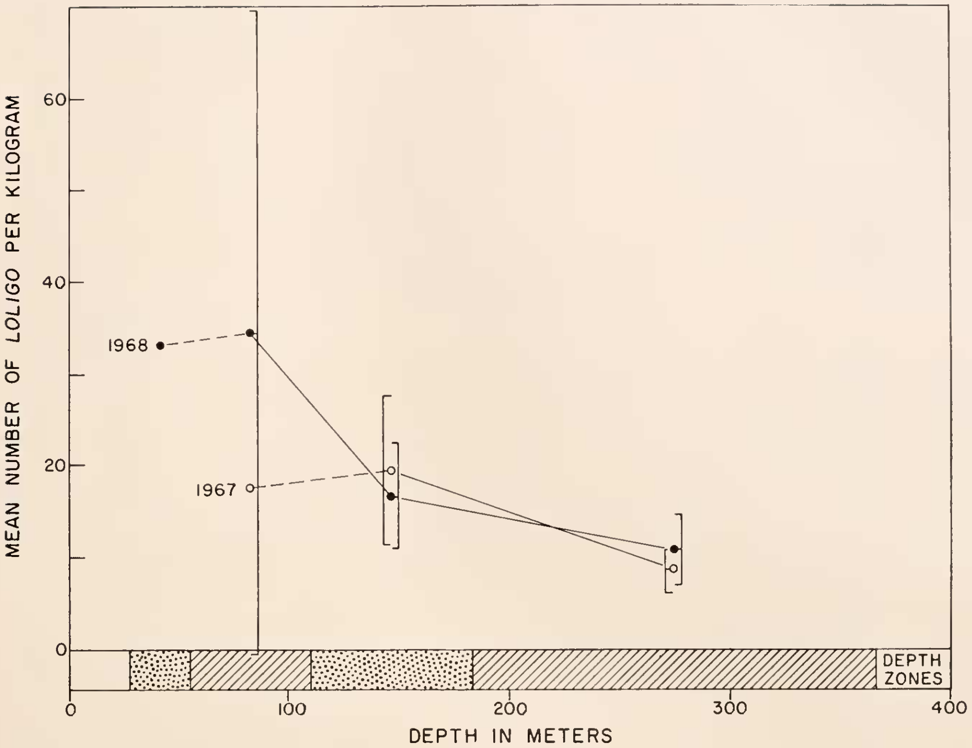

FIGURE 5. Mean number of *L. pealei* per kilogram for samples from the four depth zones in 1967 and 1968. Samples were a minimum of one kilogram in size. Bars represent one standard deviation either side of the means. Dashed lines extend to means of a single sample.

data. An arithmetic mean of the untransformed data would be greatly affected by the skewness of the data distribution and more erratic than a log mean.

Figure 3 shows the log mean catches of *L. pealei* in 1967 and 1968 for each of the nine coastal zones. Moving from southwest to northeast, there were three features in common for these two years: 1. There was a minimum abundance of squid in coastal zone II off of Chesapeake Bay. 2. The maximum abundance occurred in the center of the mid-Atlantic Bight (zone IV 1967; zone V 1968). 3. There were no catches of *L. pealei* in zone IX, on the eastern end of George Bank. The last observation was supported by nine extra tows made on the eastern end of Georges Bank during the 1968 cruise. Figure 3 indicates a high probability that a single population of *L. pealei* exists between southern Georges Bank and at least Cape Hatteras in the late winter.

Log mean catches of *L. pealei* in 1967 and 1968 are shown by depth zones in Figure 4. The 1968 data are separated into day and night portions in this figure. Very few squid were taken shallower than 110 m, or over the continental shelf. Peak abundance for the 1968 cruise (and for the two DELAWARE cruises) occurred in the 110–183 m depth zone; the 1967 cruise had an even greater catch in the deepest zone. Neither DELAWARE 67–1 nor CAMERON succeeded in catching

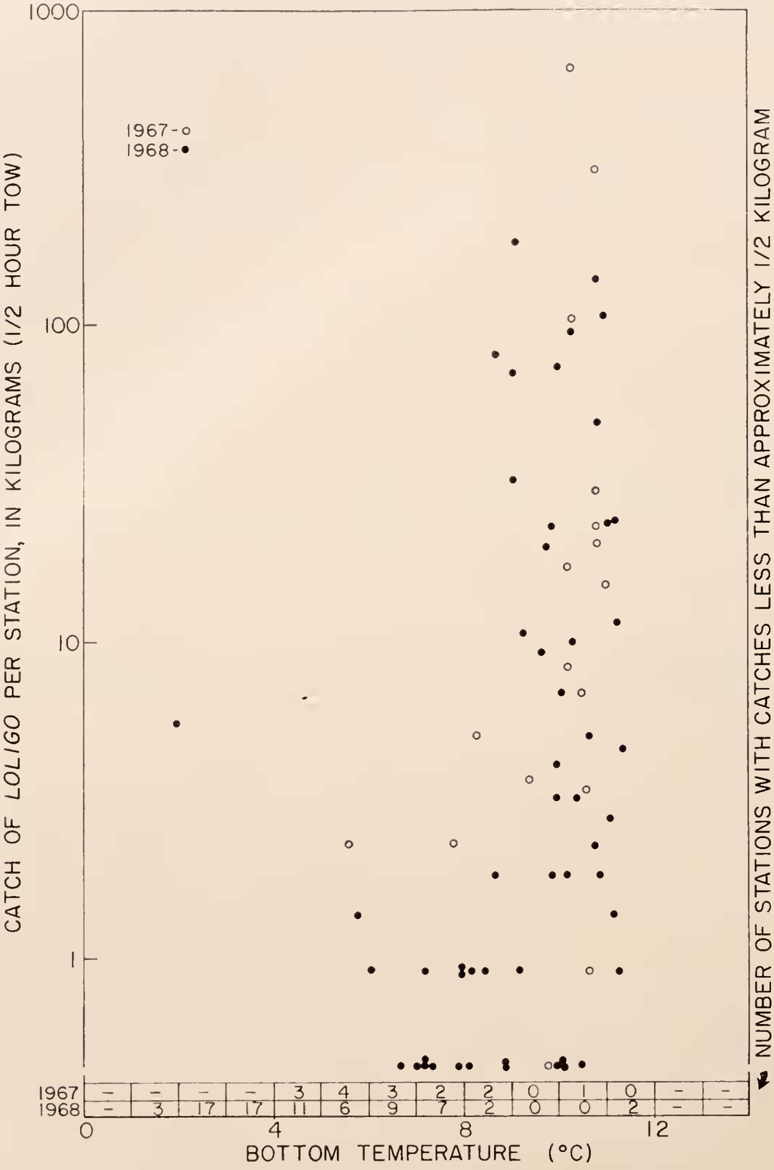

FIGURE 6. Catches of *L. pealei* per tow in 1967 and 1968 as a function of bottom temperature. Numbers of tows resulting in catches less than one-half kilogram are tabulated by year at the bottom of the figure.

L. pealei below a minimum tow depth of 366 m. Day catches were uniformly higher than night catches in 1968 and the former were remarkably similar to the 1967 data in the middle depth zones.

As previously reported (Summers, 1967) individual specimens of *L. pealei* were larger at greater depths. Figure 5 shows this relationship for measured samples of one kilogram or larger in 1967 and 1968. The trend of these data indicates a decreasing number of squid per kilogram with depth. The standard deviation shown for the 55–110 m depth zone (1968) is highly exaggerated because different size classes were found in that zone. The remaining standard deviations are approximately 30–40% of the means. The data may be converted to dorsal mantle lengths by a rough rule of thumb: Five centimeter *L. pealei* are approximately 44/kg, 10 cm *L. pealei* approximately 22/kg, 15 cm approximately 11/kg, 20 cm approximately 5.5/kg, and so on. This rule applies to fresh animals of mixed sexes, but not to squid less about 5 cm dorsal mantle length nor mature animals all of one sex.

Measured specimens of *L. pealei* ranged in dorsal mantle length 4 to 30 cm, 3 to 34 cm and 2 to 29 cm for the cruises DELAWARE 67–1, CAMERON and ALBATROSS IV, respectively. Median dorsal mantle lengths varied according to the proportions of different size classes in the measured samples; they were 12, 17 and 11 cm, respectively, for these cruises. Almost all of the female squid taken in March and April were sexually immature. Small males were mostly immature and larger ones were mostly mature (had spermatophores), the break coming at 17 cm dorsal mantle length at which size 50% of the males were considered mature. Using the same indices, Haefner (1964) found 50% of both sexes mature at a size of 8 cm in the summer time. These data suggest an annual regression of sexual development in *L. pealei* similar to that described for *L. vulgaris* (Tinbergen and Verwey, 1945).

Sex ratios in the catches were generally close to one to one, though a chi-square test applied to the larger CAMERON catches gave a probability of less than 10% that the sexes were in equal numbers. The weighting in this test was borne by a few disparate tows and could indicate local sorting of the sexes. Due to dimorphism, the sexes were not equally common for all size intervals. Attempts to separate the size classes for each sex were not conclusive. It was apparent, however that the growth of current year class *L. pealei* continues at its previously reported rate with little diminution to March and April of the first winter (see Summers, 1968). These squid had grown to a size of 12 to 14 cm dorsal mantle length in nine months. A second group of current year class *L. pealei* was found in shallow depths, south of Hudson Canyon; these had a mean size of about 8 cm dorsal mantle length.

Log mean catches of *L. pealei* are shown as a function of bottom temperature in Figure 6. It is apparent from this figure that there is a pronounced reduction in the catches at bottom temperatures below 8° C. Data from the DELAWARE cruises are not shown in the figure because these cruises were made earlier in the season when bottom temperatures were generally above 8° C.

Figure 7 shows the range of bottom temperatures for the nine coastal zones in 1967 and 1968. It should be noted that bottom temperatures increased with depth in the late winter and that 8° C temperatures were encountered everywhere in this range except in coastal zone IX. By comparison with Figures 3 and 4, it can be seen that the major catches of *L. pealei* were restricted to bottom temperatures of 8° C or higher.

The foregoing presentation of results has contrasted log mean catches of

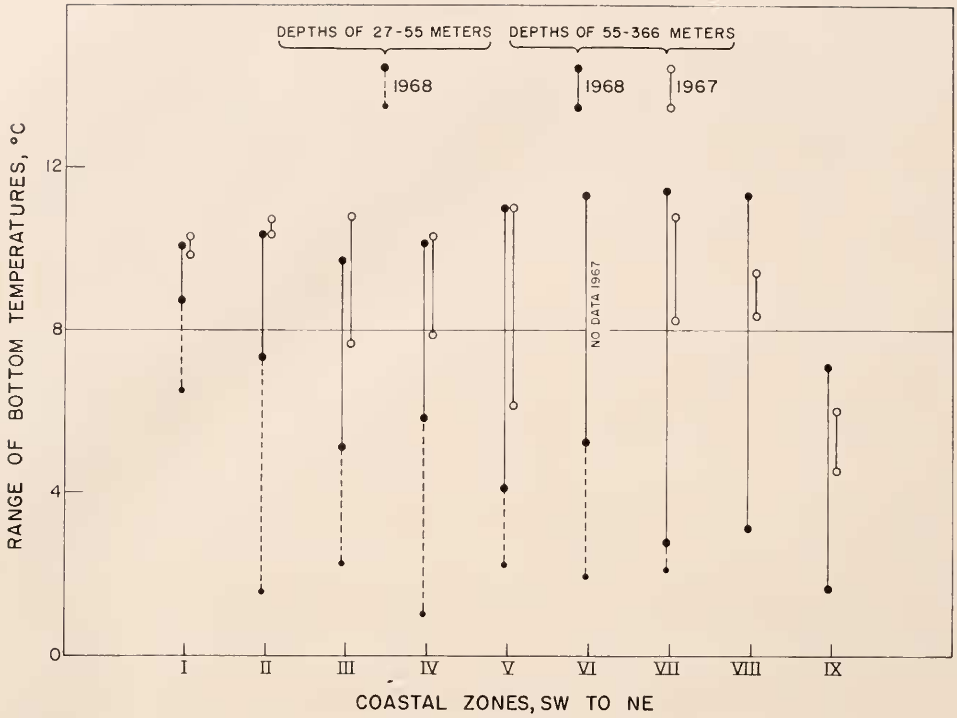

FIGURE 7. Ranges of bottom temperatures for the nine coastal zones as determined from bathythermograph records at the sampling stations during the late winters of 1967 and 1968. An 8° C isotherm is shown in the figure.

L. pealei without determining the significance of their differences. Furthermore, the CAMERON and ALBATROSS IV cruises were treated as measurements for two years, when in fact data for the two years is confounded with the two vessels and their respective gear. The year-gear factor cannot be separated with the data at hand, but the significance of this and other factors can be determined by a statistical test.

The variable which was chosen for analysis was the log transformed catch of *L. pealei* per tow for daytime trawling. The model was factorial with prime factors: depth, coastal position and the inseparable combination of year-gear. In order to make the analysis manageable, the coastal position factor was reduced to three levels by pooling coastal zones in groups of three (I-III, IV-VI and VII-IX). The depth factor consisted of three depth zones (55–110, 110–183 and 183–366 m). The year-gear factor was composed of two levels which might be designated: 1967-CAMERON and 1968-ALBATROSS IV. Through the use of a table of random numbers, data were selected to provide two replications per cell, thus discarding some of the available information at the expense of simplification. There were no data for the cell VII-IX, 55–110 m, 1967-CAMERON; these were supplied by using equivalent 1968-ALBATROSS IV data in their place. The substitution should not be troublesome because this was an especially well sampled area in 1968. Of 21 tows in that year, 12 were devoid of *L. pealei* and the remainder produced minor catches. It seems unlikely that the CAMERON would have caught large quantities of squid in this region in 1967.

The selected data were submitted to an analysis of variance with the following results: Coastal position and depth were found to be significant with better than 99% confidence. The remaining prime factor, year-gear, and all interactions were not demonstrably significant. The significance of coastal position is not readily apparent (Fig. 3) unless it is appreciated that pooling the coastal zones enhanced the contrast between the abundance of squid in the central mid-Atlantic Bight and the two ends of the Bight. The depth preference of *L. pealei* is apparent in Figure 4. The lack of significance in the year-gear factor does not imply equality between the two levels, but suggests that the years were not radically different. The actual surveys were more highly structured than the three coastal positions imply. This represents a restriction on the randomization of the error term in the analysis of variance, and probably made the results of the test conservative.

DISCUSSION

Estimates of relative abundance

It is possible to treat otter trawl catches as quantitative samples and estimate the relative abundance of a species from them. This allows a more direct comparison of biomass or numbers of individuals than contrasts of means.

Results of daytime trawling shown in Figure 2 indicate that the CAMERON (with its larger trawl) outfished the ALBATROSS IV and that the disparity was greater with larger catches. This corroborates results obtained by the use of different sized otter trawls inshore, assuming the squid population was substantially the same, and indicates further quantification of trawl catches.

The Bureau of Commercial Fisheries recently installed instruments on otter trawls which measure dimensions of the trawl while underway. In one application, Bruce (1968) measured the horizontal opening of #36 and #41 otter trawls to be 10 and 14 m, respectively. With the towing speed (6.5 km/hr) and towing time (1/2 hr), it is possible to calculate the bottom area swept by the trawl in one standard tow. Multiplying the log mean catch of *L. pealei* in any cell in the sampling matrix by the ratio of cell area to swept area results in an estimate of relative abundance of *L. pealei* (by weight) for that cell. This estimate is almost certainly lower than the population because of: squid escaping from the trawl, avoidance of the trawl, squid present above the vertical opening of the trawl and loss of specimens during the hauling of the trawl.

These losses, and probably others, make quantification of an otter trawl especially difficult. The end result is that the estimates of relative abundance probably grossly underestimate the natural population.

Overall estimates of relative abundance were calculated to be 3.4 and 2.1×10^6 kg of *L. pealei,* respectively, for the years 1967 and 1968. Owing to differences in bottom area of the various depth zones, the largest relative biomass was in the 110 to 183 m depth zone which accounted for 1.9 and 1.6×10^6 kg of *L. pealei,* respectively, for these same years. Numbers of indivduals were determined from the relative abundances through the use of results shown in Figure 5. Thus, the sampling gave overall estimates of 5.7 and 4.5 × 10^7 squid, respectively, for the years 1967 and 1968. As these estimates apply to the late winter, one month before the earliest inshore appearance of *L. pealei* near Woods Hole, and there is little likelihood of continuing recruitment, they should represent a minimal annual population. Additionally, the log mean data are conservative and produce lower estimates of relative abundance than arithmetic mean catches per tow.

Temperature

There is a striking correlation between the relative abundance of *L. pealei* and the occurrence of bottom temperatures in excess of 8° C. This mechanism alone could explain why *L. pealei* was not found in coastal zone IX and why it was taken in the 27–55 m depth zone only in coastal zones I and II (1968). Late winter bottom temperatures in the sampling region generally increased with depth to a maximum of about 10° C at 150 m depth. Similarly, temperatures over the continental shelf decreased from southwest to northeast along the mid-Atlantic Bight. These trends are shown in Figure 7.

Annual cycles of bottom temperature for the continental shelf between Nova Scotia and Hudson Canyon were reported by Schopf (1967). These data indicate that offshore bottom temperatures north of Georges Bank do not ordinarily rise above 8° C at any time of year. Thus, the appearance of *L. pealei* in the Bay of Fundy very likely is the result of seasonal inshore migrations (see Bigelow, 1924; Stevenson, 1934). Ten year mean water temperatures measured at the Portland (Maine) and Boston (Massachusetts) lightships indicate that inshore surface water temperatures exceed 8° C from late May to late November (D. F. Bumpus, personal communication). These vessels are situated over 46 and 30 m of water, respectively, and have measured bottom temperatures in excess of 8° C only during the last 2½ months of that period. Therefore, an 8° C temperature restriction of *L. pealei* would greatly limit the movements and breeding season of this animal north of Georges Bank.

Mr. Bumpus' data indicate that long term mean surface and bottom water temperatures in the vicinity of Woods Hole both exceed 8° C from early May to late November. This corresponds to the inshore season of *L. pealei* previously cited and confirms the importance of this temperature restriction. The period of temperatures in excess of 8° C is longer as one moves west and south from Woods Hole along the mid-Atlantic Bight; this suggests the possibility of a longer inshore season of *L. pealei* in that region. It could also account for the small squid taken south of Hudson Canyon in the late winter by suggesting that they result from an extended breeding season in the southern part of the mid-Atlantic Bight. *L. vulgaris* is reported to have a single breeding season in the North Sea (Tinbergen and Verwey, 1945) and a double breeding season in the western Mediterranean Sea (Mangold-Wirz, 1963); a similar extension in the breeding season of *L. pealei* could produce this effect in the mid-Atlantic Bight.

Biological implications

The migration of *L. pealei* cannot be fully described without tagging studies, but the present report on distribution and abundance can be compared with the literature on summer squid populations to indicate general limits of the migratory pattern. The northern range limit of *L. pealei* in winter is 600 km south of the reported summer range limit, and a longer migrational distance is suggested if the animal must remain inshore to avoid water temperatures below 8° C. No other evidence exists for a coastwise migration except that coastwise components in the migration would be beneficial in dispersing squid found in the central mid-Atlantic Bight in the late winter. The bulk of the *L. pealei* population is found just below the continental shelf break in late winter and these animals must migrate up to 200 km to come inshore in the spring. Hence, *L. pealei* must have a strong onshore component in its migration and probably migrates considerable distances twice each year.

It is not appropriate to place *L. pealei* in a demersal assemblage on the basis of trawl catches. Animals taken in trawls are selected by size according to species and do not necessarily represent single communities. Co-occurrence of species on the fishing grounds is the subject of continuing study by fisheries agencies and better examined with more data than is available for this study. The fact that *L. pealei* is taken with otter trawls indicates that it is demersal at least part of the time and the difference between day and night catches (Fig. 4) suggests that it disperses vertically at night.

The author wishes to acknowledge the many people who have assisted in the gathering and analysis of data presented in this report. From the Fisheries Research Board of Canada these include Mr. M. C. Mercer, Mr. Clarence Butt, the officers and crew of the A. T. CAMERON and the scientific party on cruise #130: Messrs. G. Dawe, E. M. LeGrow, E. E. Squires, W. R. Squires, P. R. Stokes, R. J. Tizzard and G. E. Tucker. From the U. S. Bureau of Commercial Fisheries, Mr. E. D. McRae, Drs. R. L. Wigley and M. D. Grosslein, the officers and crew of ALBATROSS IV and the scientific party on cruise 68–3, especially Messrs. F. E. Nichy, R. R. Marak and H. Stern, Jr. Finally, from the Systematics-Ecology Program, Miss J. M. Reinhart, who stood watches on the last cruise. Drs. N. R. Sinclair, M. R. Carriker and C. F. E. Roper read and criticized the manuscript.

SUMMARY

1. The distribution and relative abundance of *L. pealei* is reported from otter trawl sampling in the mid-Atlantic Bight during the late winter.

2. A lognormal frequency distribution of catches per tow suggests a "patchy" spatial distribution of *L. pealei*.

3. This species ranged from the southern edge of Georges Bank at least as far as Cape Hatteras in depths from 28 to 366 m.

4. Specimens of *L. pealei* were found to be especially concentrated in the central mid-Atlantic Bight at depths of 110-183 m.

5. The sizes of individual squid generally increased with depth, though there were mixtures of size classes in the 55–110 m depth zone.

6. *L. pealei* was found restricted mainly to water temperatures of 8° C or higher. This is related to the migration and summer distribution of the animal.

7. Conservative estimates of relative abundance of *L. pealei* in the mid-Atlantic Bight for the late winters of 1967 and 1968 are approximately 5×10^7 individuals.

8. Biological observations indicate an annual regression of sexual development during the winter months, the possibility of an extended breeding season south of Hudson Canyon and a continued rapid growth rate of current year class squid through the first winter.

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